

Optical photon process at XMASS MC simulation

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Current environment

✓ **GEANT4.9.3**

✓ Red Hat Enterprise Linux Server 5.6 (Tikanga)

✓ gcc 4.1.2

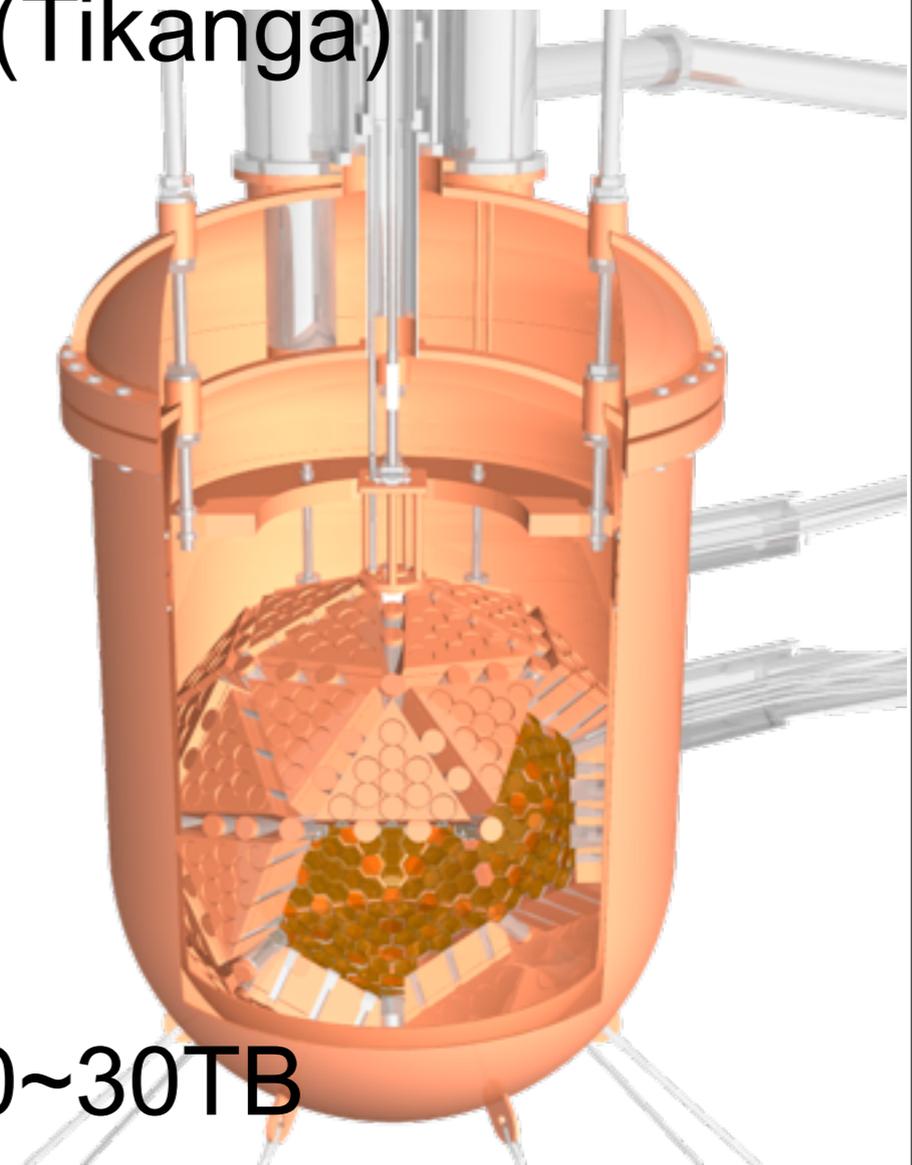
✓ Xeon E5540 x 2 / computer

- 2.53GHz

- 4 core

✓ 8GB memory

✓ Data size: Background ~1000days 20~30TB



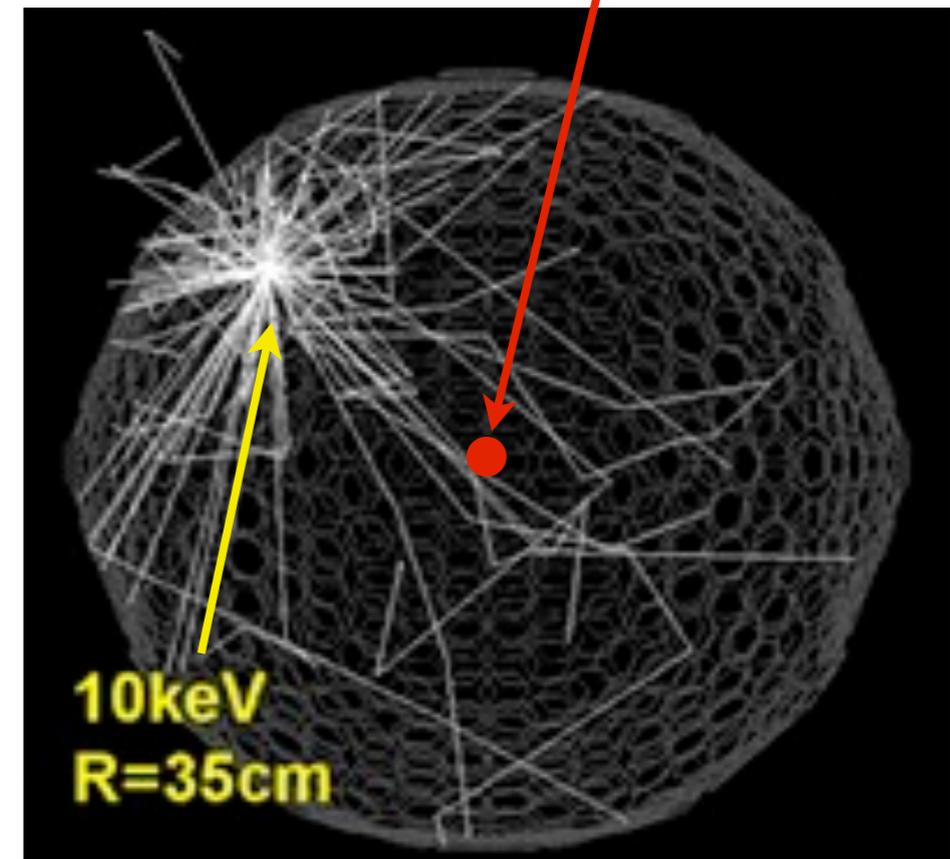
Optical photon process at XMASS

- ✓ In the XMASS detector, scintillation photons from liquid xenon are observed with 642 PMTs.(~ 15 [photons /keV])
- ✓ Need to simulate fine structure of detector.
- ✓ All optical photons are tracked.
- ✓ Process time of optical photons is dominant.

Typical process time (user time by G4Timer)

	only optical photons [sec / 10000 photons]	whole process [sec/10000photons]
662keV gamma-ray from detector center	2.6	3.3
1MeV alpha-ray from detector center	2.7	-

Alpha, gamma source at center



A simulation of optical photons in the XMASS detector

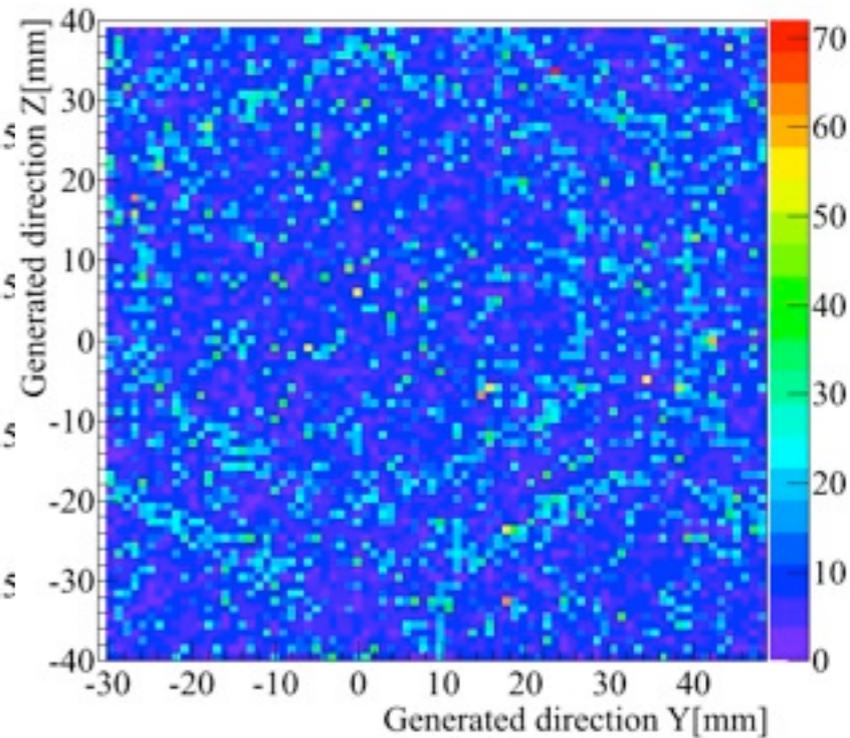
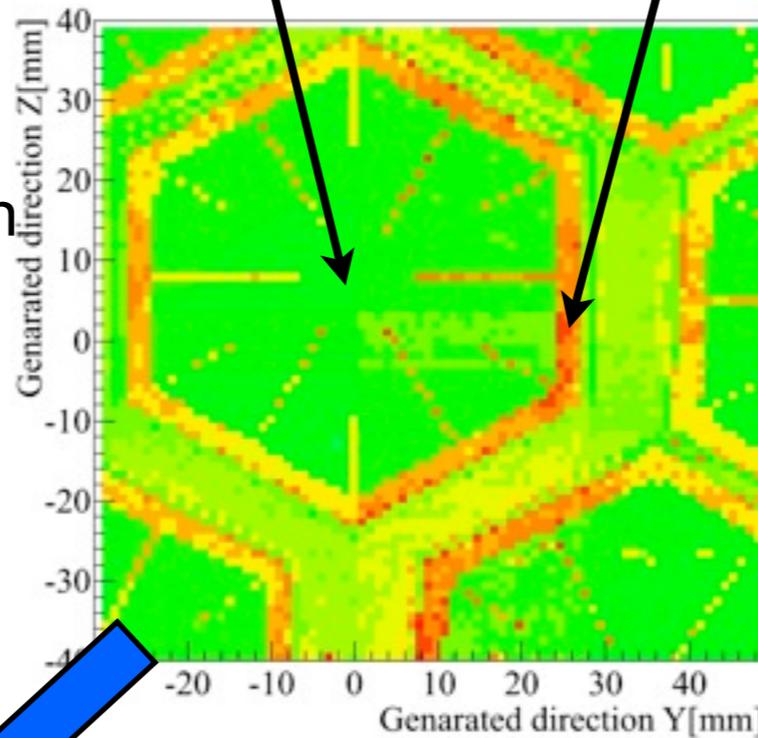
Motivation: confirm what requires time so much.

UserTime and StepNumber

- ✓ I generated 10000 optical photons directly to each direction from detector center.
- ✓ Then, I checked the process times and step numbers of tracks.

PhotoCathode: 2.5[sec]

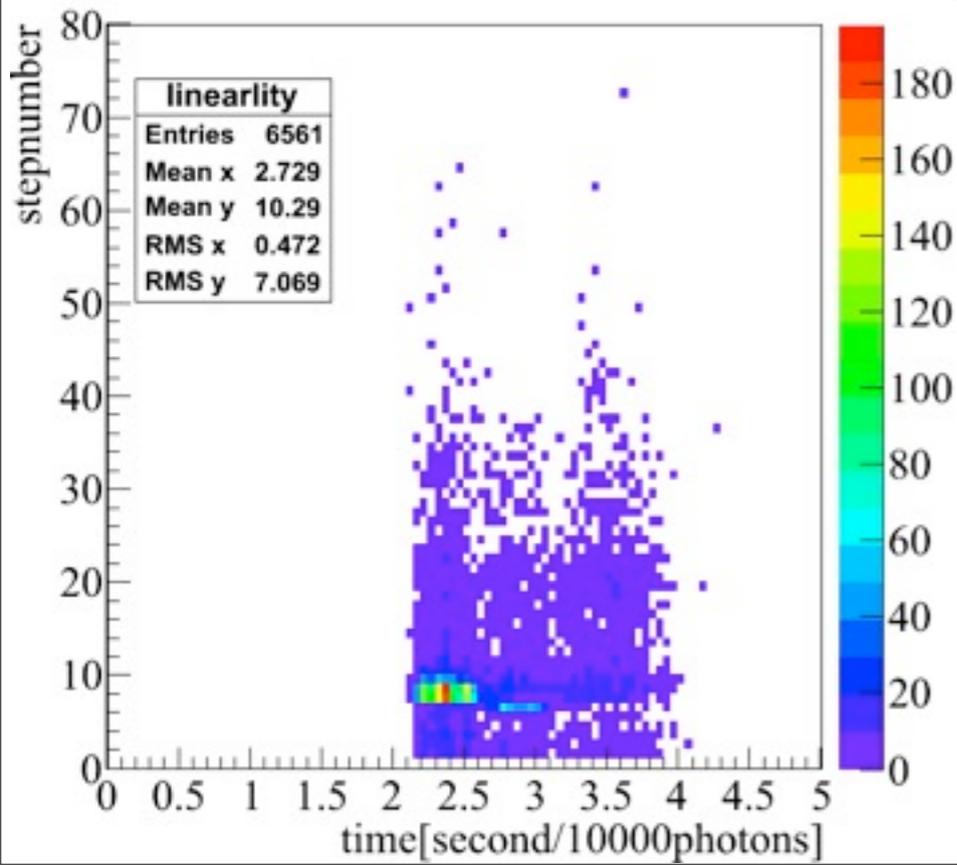
AlRing: 4.2[sec]



distribution of [sec/10000optical photons]

distribution of [step number of the 1st track]

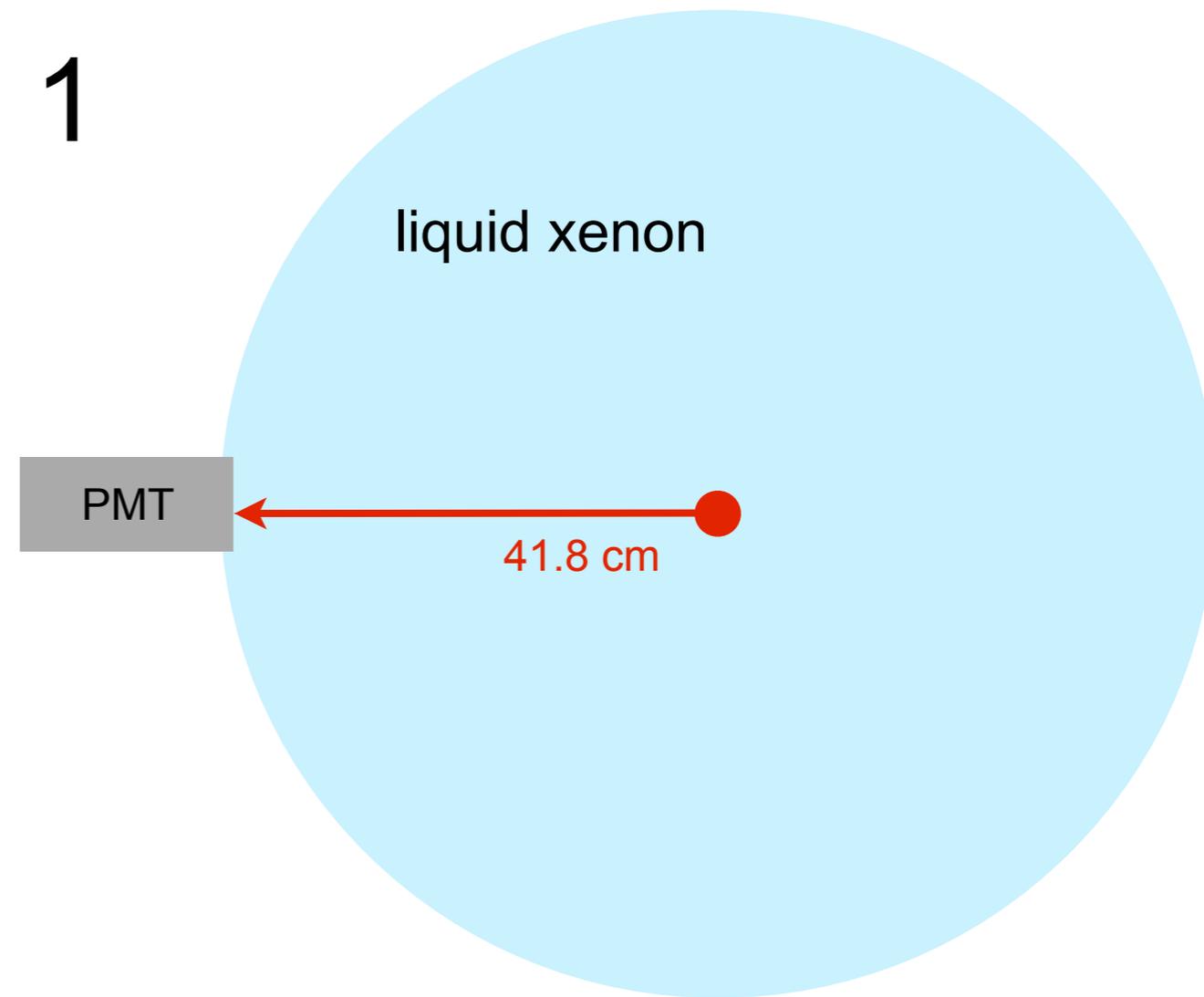
relation between time and StepNumber



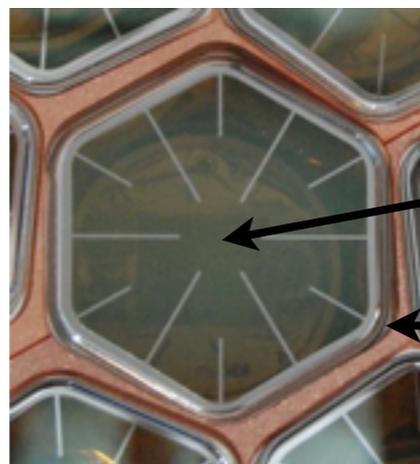
- ✓ **Process time depends on detector surface geometry.**
- ✓ **It seems that there is no linearity between process time and step number.**
- ✓ **Therefore, I looked into details.**

Study of process time 1

- ✓ For optical photons process, GEANT4 transportation sources were modified by Prof.Kurashige.(MOD version)
 - Unnecessary if statements are removed.
- ✓ Generate events from center, then compare process times [sec/10000photons].
- ✓ Some improvements are observed.
- ✓ Use MOD version for further studies.

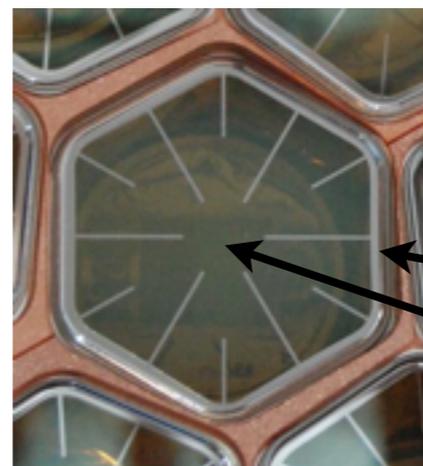
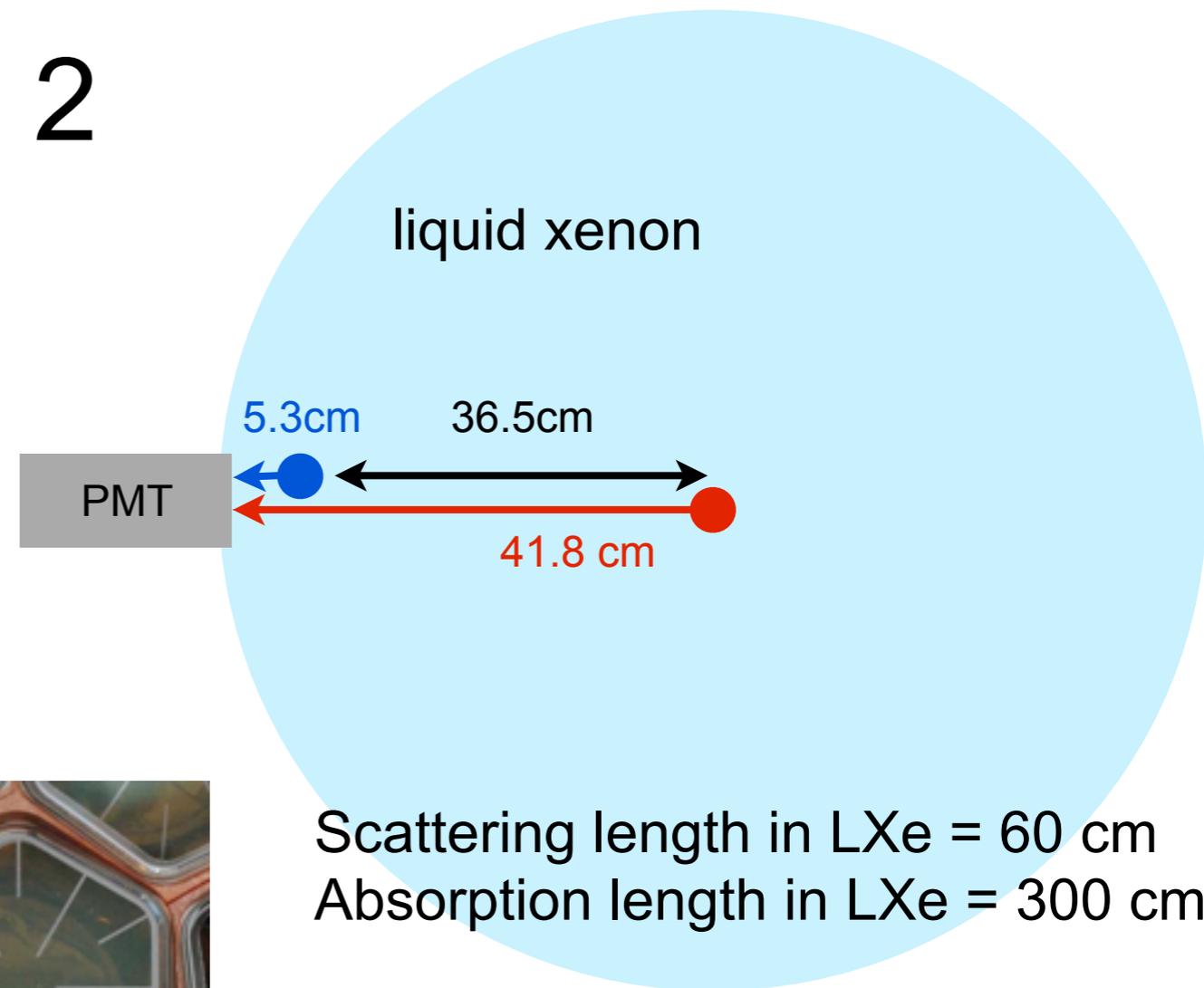


	Original	MOD
662keV gamma	2.6	2.4
1MeV alpha	2.7	2.5
optical photons to PhotoCathode	2.5	2.1
optical photons to AIRing	4.2	4.0



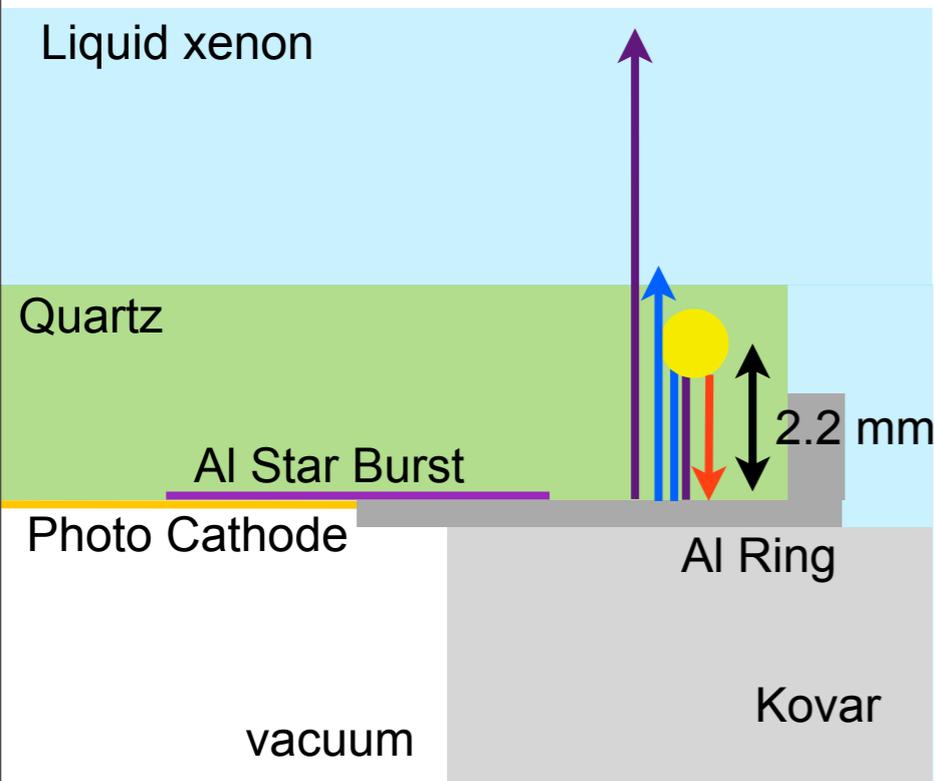
Study of process time 2

- ✓ In order to check process time in liquid xenon, generated position was moved to just before a PMT window.
- ✓ Beamed optical photons to PhotoCathode and AIRing.
 - from detector center
 - from PMT window front
- ✓ By difference between PhotoCathode cases, process time in liquid xenon would be **~ 0.1 [sec/10000/10cm].**



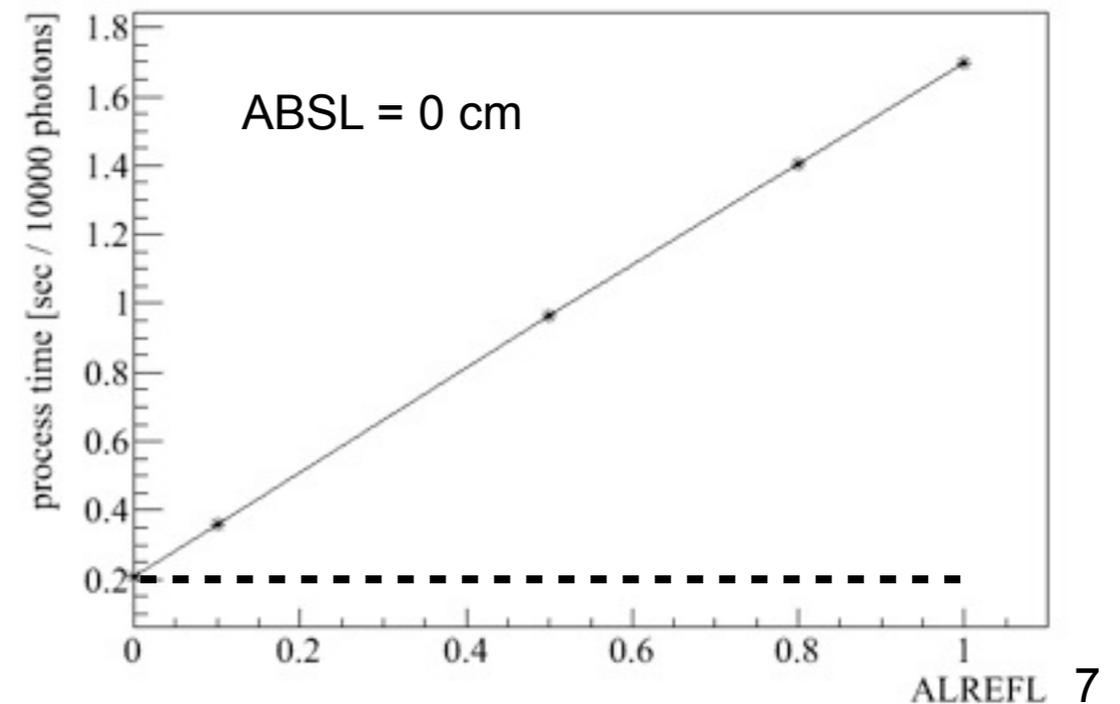
	PhotoCathode	AIRing
from PMT front	1.7	5.3
from center	2.1	4.0

Study of process time 3



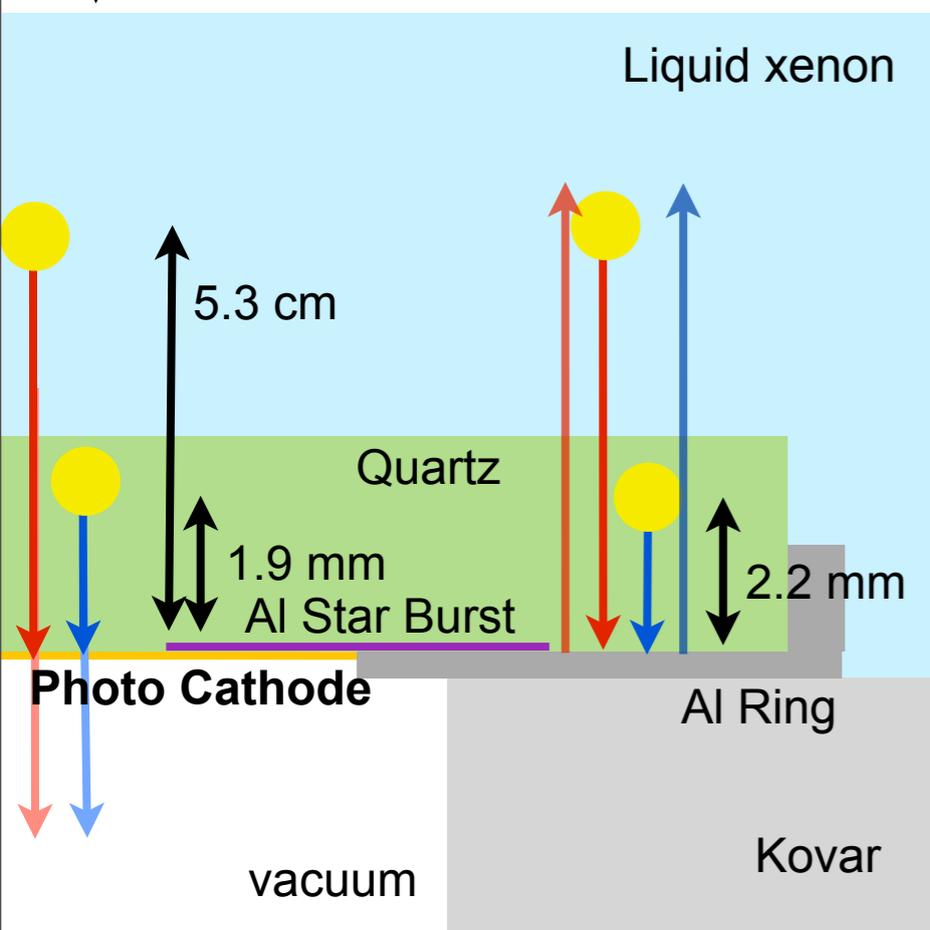
- ✓ In order to check process time around reflection at AlRing, generated position was moved to inside PMT quartz window.
- ✓ Parameters were changed.
 - LXe absorption length: **0cm, 300cm** (original = 300cm)
 - Al reflectance: **0.0 ~ 1.0** (original = 0.8)
- ✓ Offset time is ~ 0.2 [s/10000photons].
- ✓ **1.5 [s/10000photons] is required around reflection process at PMT AlRing. (1.7 - 0.2)**
- ✓ Process time after reflection is 2.9 [s/10000] ($4.6 - 1.7$).

	process time [sec/10000]	mean StepNumber
Al reflectance = 0.0 Absorption length = 0	0.2	1.0
Al reflectance = 1.0 Absorption length = 0	1.7	3.9
Al reflectance = 1.0 Absorption length = 300	4.6	14.5



Study of process time 4

- ✓ Process time between liquid xenon and PMT quartz window was estimated.
- ✓ Beamed optical photons to PMT PhotoCathode and AIRing
 - from **inside PMT quartz window** , **PMT front in LXe**
 - Absorption length = 300 cm
 Scattering length = 60 cm
 Al reflectance = 0.8
- ✓ **1.3 ~ 1.7 [s/10000] seems required for LXe -> PMT quartz process.**



	PhotoCathode	AIRing
from PMT front	1.8	5.3
from PMT quartz	0.5	3.6

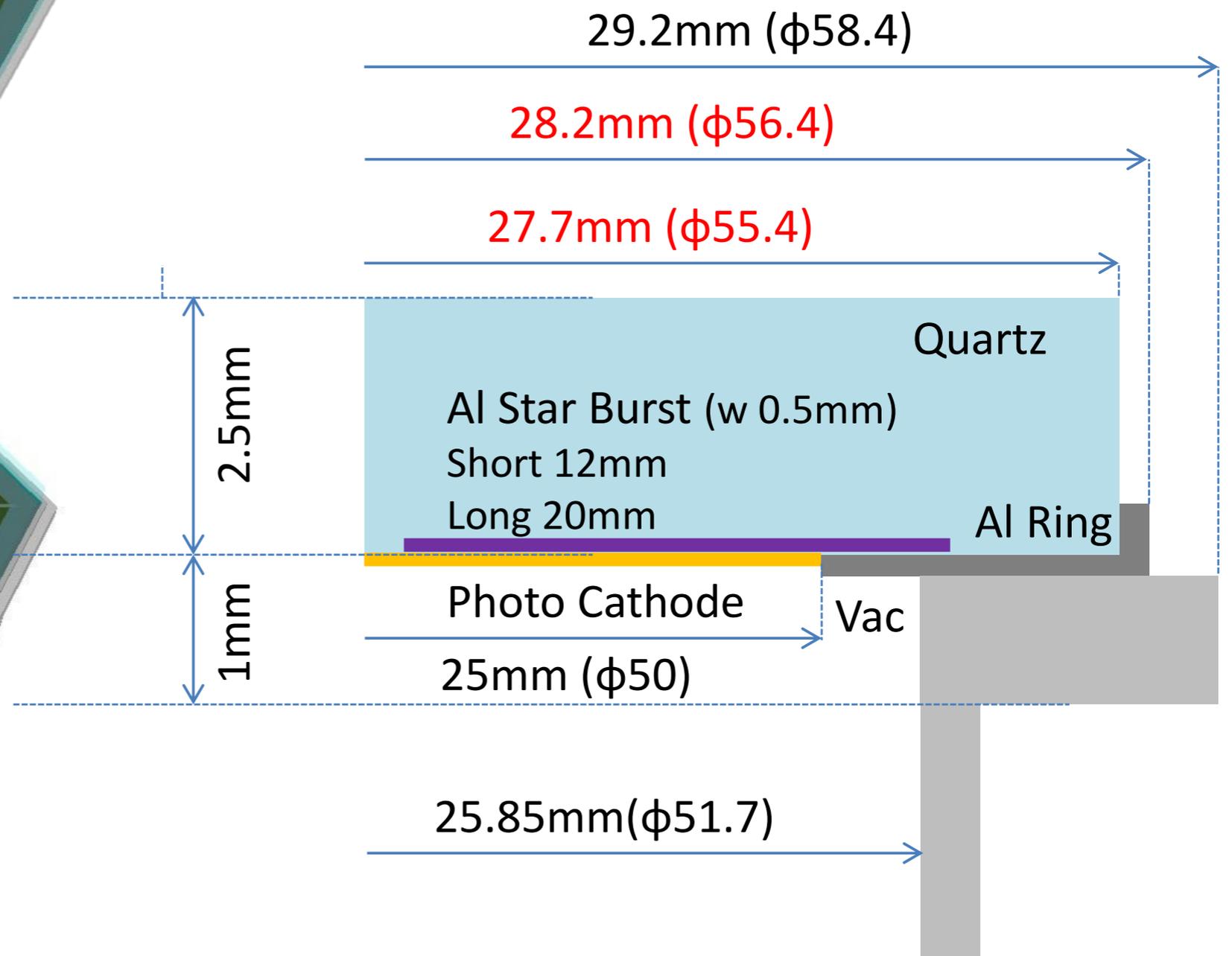
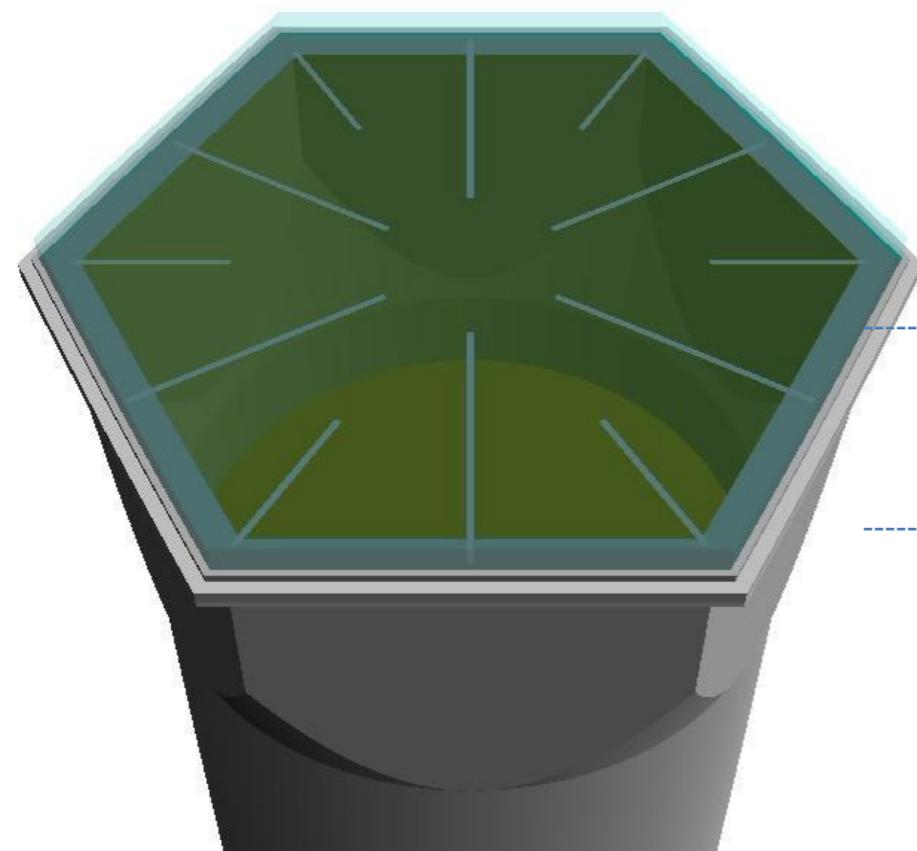
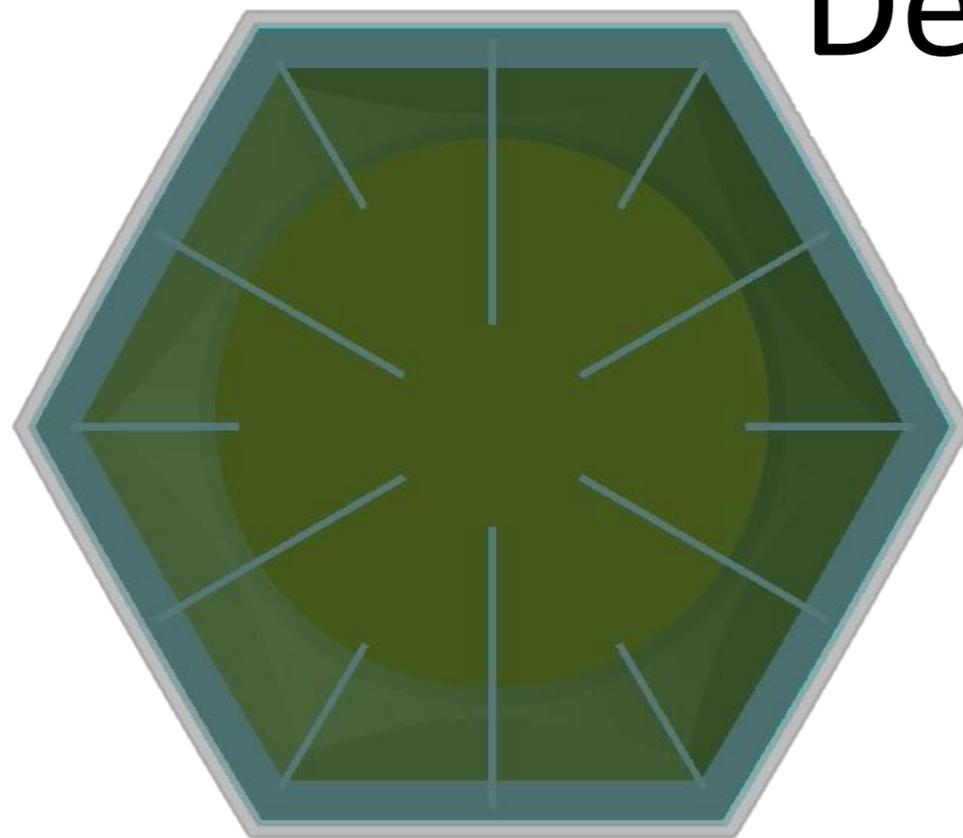
Summary

- ✓ In XMASS simulation, process times of optical photons are investigated.
- ✓ I used GEANT4 transportation sources modified for optical photons.
 - Unnecessary if statements are removed.
 - 662 keV gamma: original 2.6 -> MOD 2.4 [s/10000]
- ✓ Process times in each step are obtained as follows.
- ✓ Process 2 looks dominant in XMASS simulation.

Process	time[s/10000photons]
1. Transport in LXe(/10cm)	~0.1
2. LXe -> PMT quartz	1.3 ~ 1.7
3. Reflection at PMT AIRing	1.5
4. After reflection	2.9
5. Offset	~0.2

backup

Detail geometry of PMT



Processes and parameters.

- Energy range a few keV ~ some MeV
- Low energy electro magnetic process
 - Photo electric
 - Gamma conversion
 - Compton
 - Ionization
 - Brems
 - Multiple scattering
- Optical photon tracking
 - Absorption
 - Rayleigh Scattering
 - QE tables for each PMT
 - Scintillation
 - Spectrum of scintillation.
 - Non linearity of scintillation efficiency.
 - Refractive index for liquid xenon and quartz.
 - Wavelength dependency
 - Reflection
 - Angle dependence of reflectivity, absorption at photo cathode.